

HOST-PLANT RECORDS AND LIFE HISTORY NOTES ON NEW MEXICO TEPHRITIDAE (DIPTERA)

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Abstract.—Host relations, distributional data and life history information are presented for 12 species of Tephritidae in New Mexico. *Acirina bigeloviae* (Cockerell), *A. ferruginea* (Doane), *A. lutea* (Coquillett), *A. notata* (Coquillett), *A. trixa* Curran, *Procecidochares* sp. nr. *minuta* (Snow), and *Valentibulla dodsoni* Foote were reared from *Chrysothamnus nauseosus* (Pall.) Britt., which was identified to the subspecies level in all cases. The unusual life history of *Procecidochares* sp. nr. *minuta* is described in part and compared to other gall-forming tephritids. New hosts are recorded for *Tephritis araneosa* (Coquillett) and *T. signatipennis* Foote and considerable range extensions are noted for *Mylogymnocarena apicata* (Thomas), *Procecidochares flavipes* Aldrich, and *Rhagoletis ribicola* (Doane).

While conducting ecological studies on several tephritid fly species between 1980 and 1985, I accumulated information on distribution, host plants, larval substrates, and emergence dates, all of which are reported here. Seven of the fly species discussed are gall-formers on *Chrysothamnus nauseosus* (Pall.) Brit. Recent evidence (Wangberg, 1978, 1980, 1981; McArthur et al., 1979; Dodson and George, 1986) suggests that several species in the genera *Acirina*, *Procecidochares*, and *Valentibulla* are restricted to particular subspecies of *Chrysothamnus*. I provide identifications of *C. nauseosus* subspecies serving as hosts for seven tephritid species belonging to the aforementioned genera and describe what is known of the peculiar life history of *Procecidochares* sp. nr. *minuta* (Snow). In addition, I report the host plants of two species of *Tephritis* and collection records that represent notable range extensions for *Mylogymnocarena apicata* (Thomas), *Proceci-*

dochares flavipes Aldrich, and *Rhagoletis ribicola* Doane.

METHODS

Emergence data of gall-forming species are based on collections of galls on *Chrysothamnus nauseosus* from four localities on various dates (Table 1). Galls were brought into the laboratory and held for adult emergence after pupation had occurred in the field. Four of the seven gall-forming species were reared in large numbers as a part of other studies. Actual numbers of emergent individuals of the remaining three species are noted.

Life history information for *Procecidochares* sp. nr. *minuta* was obtained from two study areas approximately 15 km apart in Albuquerque, New Mexico. In August and September, 1981, samples of at least 20 galls were brought into the laboratory at weekly intervals where they were measured and dissected. The contents of the galls were

noted and measured. When pupation was completed in the field, several hundred galls were brought into the laboratory for adult emergence in each year from 1981–1984. Dissections of the female reproductive system were performed under a dissecting scope and the presence of sperm was determined by squashing the spermathecae on a slide under a cover slip and viewing on a compound light microscope. The spring field sex ratio of *Procecidochares* sp. nr. *minuta* was obtained by visual inspections of 12 *C. n. bigelovii* plants on 12, 22, and 23 May, 1985, at one of the study sites.

Adult *Tephritis araneosa* and *T. signatipennis* emerged from mature flowerheads which had been clipped and brought directly into the laboratory where they were held in plexiglass cages at room temperatures.

RESULTS AND DISCUSSION

SPECIES REARED FROM GALLS

Aciurina spp. and *Valentibulla dodsoni* Foote

Table 1 lists host plant subspecies, gall descriptions, collection sites and emergence dates for seven gall-forming species. It should be noted that *Aciurina bigeloviae* (Cockerell) and *A. trixa* Curran are treated herein as separate species. In a recent generic revision, Steyskal (1984) synonymized several species including *A. trixa* under the name *A. bigeloviae*. Dodson and George (1986) resurrected *A. trixa* based upon ecological and biochemical evidence. Further information on the galls and host plants of these two species can be found in Dodson and George (1986). Host plant records for *A. bigeloviae* and *A. trixa*, were compiled by Wasbauer (1972) and Wangberg (1981). Recent evidence (McArthur et al., 1979; Wangberg, 1981; McArthur, 1986; Dodson and George, 1986) indicates that these flies are extremely host specific to the plant subspecies level. Thus, there seems to be justification for questioning the accuracy

of the older records naming *Artemisia* and *Haplopappus* as hosts (Wasbauer, 1972).

Both *T. bigeloviae* and *A. trixa* galls (Figs. 1A and 1B, respectively) can occur at extremely high densities. The highest density of *A. trixa* galls (each approximately 1 cm in diameter) at the Bernalillo location was 15 galls along a 7 cm length of stem. Several plants at the Rio Grande Gorge State Park site were literally covered with *A. bigeloviae* galls (1–1.5 cm in diameter). For example, one plant roughly 1 m in diameter contained over 2000 galls. These densities are apparently the highest for any tephritid stem gall-formers. Freidberg (1984), reviewing the tephritid gall-former literature, stated that the highest density of stem galls was "probably the 135 galls of *Spathulina sicula* Rodani . . . on a small plant of *Phagnalon rupestre*."

Gall descriptions for *Aciurina ferruginea* (Doane) and *A. lutea* (Coquillett) are listed as "unknown" because the specimens emerged from large collections of *A. bigeloviae* galls. I do not know whether the *A. ferruginea* and *A. lutea* individuals emerged from galls morphologically similar to the galls of *A. bigeloviae* or from other galls collected coincidentally with those of *A. bigeloviae*. Wangberg (1981) described *A. ferruginea* galls as "smooth, pear-shaped . . . at the axillary bud on the current year's growth." No gall of this type was observed, but it could have been overlooked because several people were involved in the collection of the galls. Wangberg (1981) also described the galls of *A. lutea* as "a simple but abrupt swelling on a stem." It is possible that such a cryptic gall was included inadvertently in the collection of *A. bigeloviae* galls (small bits of the adjacent stem sometimes remained attached to the galls). Whatever the morphology of the galls, *Chrysothamnus nauseosus* represents a new host plant species for both *A. ferruginea* and *A. lutea* (see Wangberg, 1981 for a list of previously recorded host plants).

The dates of capture of adult *A. ferruginea*

Table 1. Rearing records for seven tephritid gall-formers on *Chrysothamnus nauseosus* in New Mexico.

Tephritid Species	Number Reared	Subspecies of Host Plant	Gall Description	Locality and Date of Gall Collection
<i>Acturina bigeloviae</i> (Cockerell) ¹	Many	<i>Chrysothamnus nauseosus graveolens</i>	Lateral stem gall, globular with long, thick tomentum.	Jemez Valley, Sandoval Co., 29.III.81
<i>A. bigeloviae</i>	Many	<i>C. nauseosus</i> nr. <i>consimilis</i>	Lateral stem gall, globular with long, thick tomentum.	Rio Grande Gorge State Park, Taos Co., 9.V.83
<i>Acturina ferruginea</i> (Doane)	1 ♂	<i>C. n. graveolens</i>	Unknown (see text).	Jemez Valley, Sandoval Co., 14.V.82
<i>Acturina lutea</i> (Coquillett)	1 ♂	<i>C. n. graveolens</i>	Unknown (see text).	Jemez Valley, Sandoval Co., 29.III.81
<i>Acturina notata</i> (Coquillett)	Many	<i>C. n. bigelovii</i>	Lateral stem gall, globular with short tomentum.	Albuquerque, Bernalillo Co., 19.III.81
<i>Acturina trixa</i> Curran ¹	Many	<i>C. n. latisquamens</i>	Lateral stem gall, globular with waxy, glabrous surface.	Albuquerque, Bernalillo Co., 12.IV.80; Bernalillo, Sandoval Co., 14.V.82
<i>A. trixa</i>	Many	<i>C. n. nauseosus</i>	Lateral stem gall, globular with waxy, glabrous surface.	Rio Grande Gorge State Park, Taos Co., 9.V.83
<i>Proccidochares</i> sp. nr. <i>minuta</i> (Snow)	Many	<i>C. n. bigelovii</i>	Enlarged, unopened flowerhead.	Albuquerque, Bernalillo Co., 3.X.80
<i>P.</i> sp. nr. <i>minuta</i>	Many	<i>C. n. latisquamens</i>	Enlarged, unopened flowerhead.	Albuquerque, Bernalillo Co., 10.X.81
<i>Vaentibulla dodsoni</i> Foote	1 ♂, 2 ♀♀	<i>C. n. bigelovii</i>	Simple enlargement of the stem axis.	Albuquerque, Bernalillo Co., 24.IV.82

¹ Dodson and George (1986) list 23 additional locations where *Acturina bigeloviae* or *A. trixa* were reared from *Chrysothamnus nauseosus*, but the subspecies of the host plants were not determined.

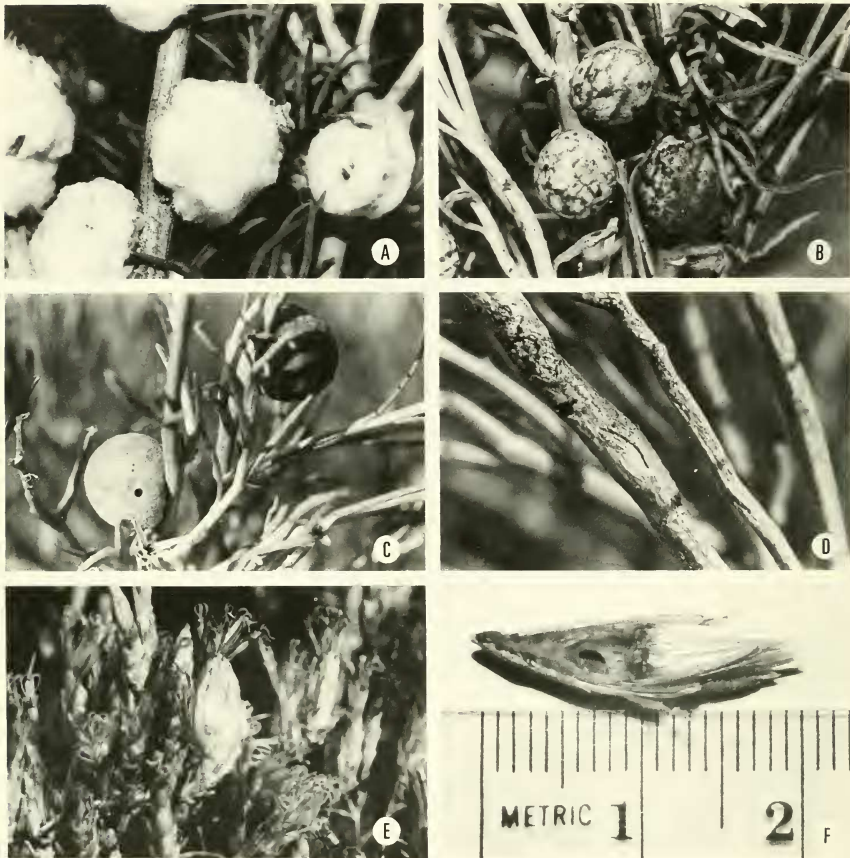


Fig. 1A-F. Galls of five species of New Mexico Tephritidae. A, *Aciurina bigeloviae*. B, *A. trixa*. C, *A. notata*. D, *Valentibulla dodson*. E, *Procecidochares* sp. nr. *minuta*. F, Cross section of *P.* sp. nr. *minuta* gall showing internal gall structure and bicolored larva.

reported in Foote and Blanc (1963) and Steyskal (1984) run from 11 June to 21 September. Steyskal (1984) noted that the dates of capture on the specimens he examined represented a late adult season compared with congeneric species. In striking contrast, I have collected *A. ferruginea* adults as early as 15 May, 1983, in Sandoval Co., New Mexico.

The following information amends some

data reported in Steyskal (1984). The record for *A. lutea* from New Mexico listed in Steyskal (1984, p. 595) should be amended to read: Sandoval County, 4 mi N San Ysidro, 29.III.1981, 1 male reared by Gary Dodson from *Chrysothamnus nauseosus* ssp. *graveolens*. This corrects the county of the collection, clarifies the host species and omits the reference to "wooly" galls since, as stated above, a simple stem gall could

have been overlooked. The date given represents the date that the galls were collected; the emergence of the *A. lutea* male occurred on 15 April in the laboratory.

The host plant record of *C. nauseosus* ssp. *bigelovii* (Gray) Hall and Clements for *A. notata* (Coquillett) (Table 1) amends the record of *Chrysothamnus* sp. in Steyskal (1984, p. 596). Like *A. lutea*, *A. notata* has rarely been collected. The only documented host plant species for *A. notata* is *C. nauseosus* (Wasbauer, 1972) and I believe it is strictly associated with subspecies *bigelovii*. Wasbauer (1972) reports *C. bigelovii*, *C. n. ssp. albicaulis*, and *Chrysothamnus* sp. as host records for *A. notata*. *C. bigelovii* (Gray) Greene is now considered a subspecies of *C. nauseosus* (Martin and Hutchins, 1981). Wasbauer (1972) attributed the record for subspecies *albicaulis* to Cockerell (1900), who originally reported the host as *Bigelovia* (*Chrysothamnus*) *graveolens* and the locality as Santa Fe, New Mexico. This record cannot be correct as it stands because the subspecies *albicaulis* does not occur in New Mexico (Martin and Hutchins, 1981). Based on my knowledge of the fly species and its host plant in this area I believe that the appropriate amendment of the Cockerell (1900) host record is *C. n. bigelovii*. The gall of *A. notata* was described by Cockerell (1900) and is shown in Fig. 1C. Although the only reported collections of *A. notata* have been in north central New Mexico (Steyskal, 1984), I have seen identical galls on *C. n. ssp. bigelovii* plants near Pagosa Springs, Colorado.

Valentibulla dodsoni Foote is a recently described species (Blanc and Foote, 1987) from New Mexico which represents a considerable range extension for the genus. *Valentibulla* was established by Foote and Blanc (1959) and the other 5 members of the genus are restricted to California, Idaho, Nevada, Oregon, Utah, and Washington (Blanc and Foote, 1987). The host plant reported here, *C. n. ssp. bigelovii*, is added to the only other host plant records for this

genus: *C. parryi* and two other subspecies of *C. nauseosus* (Wangberg, 1978). The gall of this species is a rather inconspicuous swelling of the stem (Fig. 1D). The biology and behavior of *V. dodsoni* is described elsewhere (Dodson, 1987).

***Procecidochares* sp. nr.
minuta (Snow)**

Under existing taxonomy this species would be classified as *Procecidochares minuta* (Snow). However, R. H. Foote, on the basis of his preliminary revision of this genus concludes that the *minuta* complex contains several undescribed species, hence the official designation of *Procecidochares* sp. nr. *minuta* is acknowledged (R. H. Foote, personal communication) and *Procecidochares* sp. is used in the following discussion. The following information pertains to *Procecidochares* sp. reared from *C. n. ssp. bigelovii*, not *C. n. ssp. latisquameus* (Table 1). *Procecidochares* flies from these hosts may be different species.

The life history of *Procecidochares* sp. is different from any other reported for tephritid species. Eggs are laid in May on *C. n. bigelovii* in what appears to be the apical buds of the current year's new growth. Larvae feed inside galls which become recognizable only when the flowerheads begin to form (generally July–August). *Procecidochares* sp. galls consist of enlarged, unopened flowerheads (Fig. 1E–F). Pupation takes place within the galls. The first puparia were found on 19 and 23 August, 1981, at the two study sites and the percentage of the gall samples containing puparia reached 95% by 16 and 19 September. The first adult emergences followed within a few days in both the field and laboratory.

In all four years of rearing adults in the laboratory from field collected puparia, the peak of male emergences occurred two days ahead of the female peak. Sex ratios of the emergent adults did not differ significantly from 1:1 (45 males:48 females, 1981; 62:66, 1982; 343:320, 1983; binomial tests, $P >$

0.3 in all cases) except in 1984 when there was a slight female bias (457:569, binomial test, $P < 0.001$). However, adults were already emerging when the 1984 sample was collected and, therefore, the protandrous emergence pattern already described may account for the smaller number of males. Adults lived 2–3 weeks in laboratory cages with only water supplied. Nothing is known about adult dietary requirements for this species. Females had relatively large ovaries at emergence and mature eggs by 5–6 d old. Matings occurred in the laboratory between newly emerged individuals, but no sperm transfer could be documented until females were 5 d old.

The emergence of *Procecidochares* sp. adults in late September and October is unusually late for temperate zone, univoltine tephritid gall-formers. By the end of October the average nighttime low temperature in Albuquerque is 37°F (2.7°C). *Eutreta diana* Osten Sacken has a similarly late adult season in Texas (Benbow and Foster, 1982). The 13 species studied by Wangberg (1978, 1980, 1981) in Idaho, including three species of *Procecidochares*, as well as the six remaining gall-formers reported herein, emerge earlier in the year. An undescribed species of *Procecidochares* is facultatively bivoltine in the milder southern California climate (Silverman and Goeden, 1980).

Upon emergence, adult *Procecidochares* sp. leave their larval host plant and fly to a nonhost plant, *Atriplex canescens*, which serves as the arena in a lek mating system (Dodson, 1986). Sex ratios at the *A. canescens* plants are heavily male biased. After mating, females and eventually males disappear from *A. canescens*. The status of *Procecidochares* sp. for the next six months is unknown. Adults appear again in May in large numbers on *C. n. bigelovii*. Again sex ratios are highly skewed towards males (three censuses revealed male-female ratios of 20:4, 71:36, and 69:31; binomial tests, $P < 0.001$ in all cases). One to three flies per

census were also found on *A. canescens* at this time. Half of the 36 females observed on *C. n. bigelovii* on 22 May, 1985, were either mating or ovipositing when first seen.

At least two hypotheses may account for the period from November to May. Flies might be overwintering as adults in an unknown location, or females might be ovipositing in the fall on an undetermined second host. In the latter case the new generation presumably would overwinter in the egg or larval stage, emerge as adults from the second host in the spring and return to *C. n. bigelovii*. Either of these scenarios would be unique among tephritids from temperate climates where relatively cold winters are the norm. Most tephritid gall-formers studied in the western United States (e.g. Wangberg, 1978, 1980, 1981; Silverman and Goeden, 1980; Benbow and Foster, 1982; Dodson, 1987) overwinter as eggs or larvae with continuous generations on the same host. Overwintering adults (e.g. *Trupanea bisetosa*, Cavender and Goeden, 1982) are known only from milder climates. The multivoltinism of *Procecidochares australis* Aldrich results from a sequential change from galling flowerheads to galling stems, but on the same host (Huettel and Bush, 1972). A potentially parallel example to the one discussed here concerns *Myopites cypriacus* Hering, which galls the flowerheads of one host in the spring and summer and then galls flowerheads of a different host in the fall in Israel (Friedberg, 1979).

Regardless of which life history pattern turns out to be accurate for *Procecidochares* sp., intriguing consequences are posed for male mating behavior. If the flies observed in fall and spring are separate generations, then male mating strategies must alternate between generations. Adult males emerging in the fall must compete for mates within leks (Dodson, 1986), while spring emerging males search for females at oviposition sites. Alternatively, if spring males are the same generation as the fall (as a result of adult

Table 2. Biological comparison of *Procecidochares* sp. in New Mexico and *Procecidochares* sp. C in Idaho (Wangberg, 1980).

	<i>Procecidochares</i> sp. (Dodson, this Paper)	<i>Procecidochares</i> sp. C (Wangberg, 1980)	
Gall morphology		Identical	
Larvae/gall	All monothalamous	Monothalamous/polythalamous	
Gall length (mm)			
Average:	20.8	11.3	12.6
Range:	18.5-23.5 (n = 21)	7.0-13.5 (n = 15)	8.0-18.0 (n = 17)
Gall width (mm)			
Average:	5.2	4.5	6.9
Range:	4.5-5.5 (n = 21)	3.0-6.0 (n = 15)	5.0-9.0 (n = 17)
Larval length (mm)			
Average:	3.6		not given
Range:	2.5-4.15 (n = 7)		2.4-3.1
Pupal length (mm)			
Average:	3.5		not given
Range:	2.7-3.9 (n = 20)		2.8-3.5
Gall initiation	Mid-summer	Mid-summer	
Adult emergence	Late September-Middle October	Late August-Middle September	

overwintering), then the same individuals possess dual mating strategies contingent upon time of year. In either case a relatively complex behavioral repertoire is implicated.

Procecidochares sp. in New Mexico may be the same species as Wangberg's (1980) *Procecidochares* sp. C in Idaho. Table 2 compares biological information on the two populations. Externally the galls of each appear identical (see Fig. 7 in Wangberg, 1980), although there may be some variation in size. Wangberg (1980) described and figured sp. C larvae and pupae with a dorsal patch tanned dark brown. This condition was evident for some but not all of the New Mexico species (49 of 74 larvae, 20 of 75 pupae). Perhaps the most distinctive biological difference was the number of larvae occupying the galls. Wangberg (1980) found both polythalamous and monothalamous galls. I dis-

sected 236 galls and never found more than one tephritid larva or evidence of more than one larval chamber.

Wangberg (1980) did not observe females ovipositing on the larval host plant but assumed, based on knowledge of two locally occurring congeners, that oviposition did occur and the species overwintered as eggs. He posed two alternatives: that adult flies overwintered or that rapid development took place allowing overwintering in the larval stage. As stated above, another possibility is a sequential host system.

SPECIES REARED FROM FLOWERHEADS

Tephritis spp.

The following two species were reared from puparia in the flowerheads of their respective host plants. Data include the fly species, number of specimens, host plant,

and the locality and date of flowerhead collection. Information on the numbers of males and females in the *Tephritis araneosa* rearings are not available at this time.

Tephritis araneosa (Coq.); 16 adults, *Chrysothamnus nauseosus* ssp. *graveolens*; mile marker 29 on NM68, Taos Co., 23.VIII.81.

T. signatipennis Foote; 11 males, 4 females; *Machaeranthera aquafolia*; 16 mi N Jemez Springs on NM4, Sandoval Co., 30.VIII.1981.

These morphologically similar species are both widespread throughout the western United States and Baja California, but this is only the second New Mexico record for *T. signatipennis* (F. L. Blanc, personal communication). Pemberton et al. (1985) list *Machaeranthera canescens* and *Saussurea americana* as hosts for *T. signatipennis*, and *Senecio serra* is the only other host known (F. L. Blanc, personal communication). By contrast, *T. araneosa* has been reared from a wide variety of host species including *C. nauseosus* (Wasbauer, 1972), but no previous report exists for the subspecies *graveolens*.

REMAINING SPECIES RECORDS

On 5 August, 1981, sixteen species of tephritids were hand collected off sunflowers, *Helianthus annuus*, at the Sandia Peak Ski Area, Bernalillo Co., New Mexico. Many of these species were undoubtedly transients on the sunflowers. Among these tephritids were two uncommon species, *Mylogymnocarena apicata* (Thomas) (2 females, 1 male) and *Procecidochares flavipes* Aldrich (1 female). These are the first New Mexico records for both species. *M. apicata* is extremely rare, collected previously only in Colorado and Mexico (Foote, 1960; R. H. Foote and A. L. Norrbom, personal communications), while *P. flavipes* records are limited to California and Mexico (Foote, personal communication). Wasbauer (1972) lists *Brickellia* sp. (cited as "Huettel, un-

published record") as the only host record for *P. flavipes*. R. D. Goeden (personal communication) has reared *P. flavipes* from two species of *Brickellia*. There is no host information to date for *M. apicata*.

The final species, *Rhagoletis ribicola* Doane, likewise has been reared from only one plant genus, *Ribes* (Wasbauer, 1972). However, this record represents an extreme range extension for *R. ribicola*. Previously known only from British Columbia (Canada), California, Idaho, Oregon, Washington and Wyoming (Bush, 1966; F. L. Blanc, G. L. Bush, and R. H. Foote, personal communications), there is at least one state between New Mexico and all other collection sites. The New Mexico population was discovered on currant plants (*Ribes* sp.) in the Sandia Mountains outside of Albuquerque. The host plant no doubt is restricted to mesic, mountainous habitats in the mainly arid climate of this region. It is not known whether this *R. ribicola* population represents an isolated, relic population left from a more favorable climatic period in the southwestern U.S., or part of an undocumented southerly migration from ancestral populations in the northwestern U.S. In either case, it would be of interest to check for *R. ribicola* populations during the fruiting season of *Ribes* spp. in Arizona, Colorado, and Utah.

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resulted in the discovery of the *Rhagoletis ribicola* population, and Durant McArthur for sharing his knowledge of *Aciurina* galls in Utah. Finally I wish to dedicate this paper to Richard H. Foote in honor of his past and ongoing career in tephritid taxonomy. This paper and others could not have been written without his frequent assistance, which he gave under no obligation and with no expectation of reciprocity. I know that I echo the appreciation of many others whom he has encouraged through the years.

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